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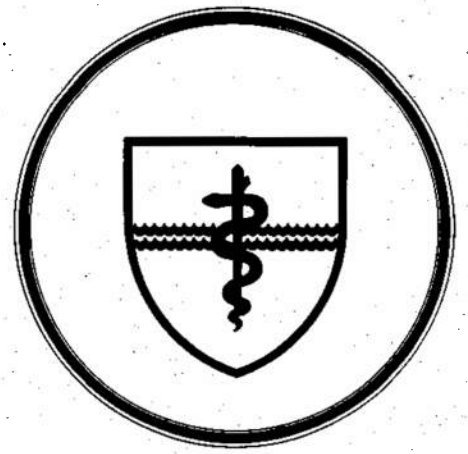

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THE X-CHROM LENS
FOR CORRECTION OF COLOR DEFICIENCY

by

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The X-Chrom Lens for Correction of Color Deficiency

Helen M. Paulson

A new device called the X-Chrom®[13,15] lens is being marketed today as an aid to the color defective in making color judgments. This device, consisting of a red lens over one eye, is not a new idea. As long ago as 1837, Seebeck[11] proposed the use of filters for aiding color defectives. In 1894, Mauthner[8] recommended the use of a red filter in front of one eye only. Cornsweet[3] popularized the idea under the title "A cure for color-blindness," and gave a description of how a color defective individual could learn to use the differential input of his two eyes to discriminate colors.

The underlying explanation for the use of any filter is that colors which normally look alike to a color defective can be differentiated by brightness and chromaticity differences. For example, a dichromat is not able to distinguish red from green, as both appear yellow to him. A red filter will decrease the brightness of the green much more than that of red; he can then alternately compare the scene through his two eyes and learn to call the darker color green and the lighter one red. Moreover, observing the colors simultaneously with the naked eye and through the red lens enhances some saturated colors, making them more vibrant and lustrous. The color defective still does not, of course, perceive colors as a normal does.

While not new, the X-Chrom lens is unique in two respects: it employs a contact lens as the filter and it has gained widespread acceptance. It is estimated that several thousand color defectives have been fitted with this lens and over a dozen reports have claimed improvements in color vision.[1,2,4,9] A few reports[7,10,14] have failed to support these claims. The present report is another evaluation.

Description of the X-Chrom Lens

The X-Chrom lens is a corneal, hard contact lens applied to one eye, usually the non-dominant eye. The lens transmits light substantially only in the red zone, from 590 to 700 nm. The inventor[12] of the X-Chrom lens states that: it is not effective for tritans and less effective for dichromats than for anomalous trichromats; that it is not applicable to those with corneal pathology or monocular vision; that it reduces visual acuity to 20/40 or better; and that most patients dislike wearing the lens in reduced illumination and at night. He further states that: the lens is not a cure but an aid which provides clues for better color vision; that it is not to be used by persons with binocular problems (such as amblyopes and suppressors); that motivation is of extreme importance; and that the binocular disturbance, fluorescence, and depth perception problems tend to disappear with time. He goes on to cite case histories of many previously disqualified color defectives who, following their adaptation to the X-Chrom lens, obtained color-judging jobs with telephone companies, electronic companies, law enforcement agencies, or finally received operating licenses from the US Coast Guard and the Federal Aviation Association.

Table I NSMRL battery of color vision tests for classification of Protans and Deutans

Category	Plate Test	Anomaloscope	Farnsworth Lantern	Dichotomous-15 Test	H-16 Test
Normal Trichromats	PASS	Yellow to Yellow match	PASS	PASS	PASS
Mild Anomalous Trichromats	FAIL	Prots match a Red to Yellow; Deuts match a Green to Yellow	PASS	PASS	PASS
Moderate Anomalous Trichromats	FAIL	Prots match a Red to Yellow; Deuts match a Green to Yellow	FAIL	PASS	PASS
Severe Anomalous Trichromats	FAIL		FAIL	FAIL Protans have a Protan profile; Deutans have a Deutan Profile	PASS
Dichromats	FAIL		FAIL	FAIL Prots have a Protan profile; Deuts have a Deutan profile	FAIL Prots have a Protan profile; Deuts have a Deutan profile

Results

I was requested to evaluate the color vision of two men who had been fitted elsewhere with X-Chrom lenses and had been using the device long enough to become well adapted to it. Subject #1 was a candidate for certification as an airman and was sent here by a Federal Air Surgeon serving with the Federal Aviation Administration in Washington, D.C. Subject #2 was a US Navy hospital corpsman who desired qualification as a corpsman aboard submarines and had been fitted with an X-Chrom lens by a US Navy optometrist in Florida. Subject #1 was classified by the NSMRL Battery of Color Vision Tests (Table I) as a severe protanomalous trichromat, and Subject #2 as a dichromatic deuteranope.

The results of their performance on an extensive battery of color vision tests with and without the X-Chrom lens are found in Table II. Subject #2 had been fitted with a neutral lens for his "naked" eye, and so he was additionally tested with the X-Chrom lens in one eye and the neutral lens in the other eye.

As can be seen in Table II, subject #1 failed all tests but one, the H-16 test, without his X-Chrom lens; this classified him as severely anomalous instead of a dichromatic color defective. With his X-Chrom lens, he also failed all tests but one—again, the H-16 test. While he did make fewer errors on all plate tests but the Hardy-Rand-Rittler with his X-Chrom lens, his performance was poorer on the Farnsworth Lantern, the Dichotomous-15 Test, and the H-16 Test; he performed better on the Farnsworth-Munsell 100-Hue test and on the Air Force Color Threshold Tester, but his scores

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were still not in the normal range. On the Hecht-Shlaer Anomaloscope, his red to green ratio was more extended with the X-Chrom lens at both the red end and the green end of the scale. Finally, his after-image performance with and without the X-Chrom lens was similar to that of severe and dichromatic color defectives; that is, he reported yellow, blue, and red after-images instead of yellow, followed by orange, then red, purple, blue, and green.

An examination of incorrect responses showed that, with his X-Chrom lens, Subject #1 made deutan instead of protan confusion errors on the Hardy-Rand-Rittler Plate Test, the Dichotomous-15 Test, and the H-16 Test. Also, on

Table II . Color vision test results on two color defectives with and without the X-Chrom lens

Tests	Subject #1 Severe Protanomalous		Subject #2 Dichromatic Deutanope		
	Without lens	With X-Chrom lens	Without lens	With X-Chrom lens	With X-Chrom lens one eye; neutral lens other eye
NSMRL Plates (14)	F (14x)	F (10x)	F (13x)	F (6x)	F (8x)
Dvorine Plates (14)	F (14x)	F (7x)	F (13x)	F (6x)	F (9x)
Ishihara Plates (16) (14)	F (16x)	F (11x)	F (14x)	P (2x)	F (8x)
Hardy-Rand-Rittler Plates Classification	Medium Protan	Medium Deutan	Strong Deutan	Mild; undiagnostic as to type of defect	Strong Deutan
Farnsworth Lantern	F (7x)	F (7.5x)	F (6.5x)	F (5.5x)	F (6x)
D-15 Test	F (2 cross-overs)	F (4 cross-overs)	F (12 cross-overs)	P (1 cross-over)	F (5 cross-overs)
H-16 Test	P (0 cross-over)	P (3 cross-overs)	F (10 cross-overs)	P (1 cross-over)	F (5 cross-overs)
Farnsworth-Munsell 100-Hue Test	183	168	254	316	322
Air Force Color Threshold Tester (64)	25 correct	33 correct	28 correct	11 correct	16 correct
Hecht-Shlaer Anomaloscope range of matches	R-G: 20-70 Y : 17-43	10-80 18-35			
After-image	Reported only yellow, blue, & red	Same Report			

Note: F = failed test; P = passed test; x = wrong.

the latter two tests he made many undiagnostic (neither protan nor deutan) cross-overs. On the Farnsworth Lantern Test, his errors with the X-Chrom lens were more serious because he doubled the number of times he mistook red and green.

Subject #2 performed better with his X-Chrom lens on many tests; indeed, he even passed three tests which he failed without the lens. However, on the Farnsworth-Munsell 100-Hue Test and the Air Force Color Threshold Tester, he performed significantly poorer.

With the Naval optometrist's prescription of X-Chrom lens in one eye and neutral lens in the other, he failed all tests and again did significantly poorer on the F-M 100-Hue Test and the Air Force Color Threshold Tester.

Discussion

For any device or procedure purported to help color defectives, the crucial issue is whether or not the color defective is assisted in performing color-related tasks in the real world, not whether it enables him to pass screening tests. Historically, there have been a number of incidents in which color defective men were enabled to pass tests, but not otherwise improved. For example, color vision tests all have exacting conditions for administration and, when these conditions are not followed precisely, incorrect diagnoses will result. If a color vision test is administered at an incorrect viewing distance, or at an incorrect speed, or under an incorrect illuminant, and a color defective person passes the test, this in no way means the person is color normal and sees colors in the real world as a normal does.

Most of the reports which support the X-Chrom lens as an aid for color defectives merely indicate improvement on pseudo-isochromatic plate tests. Such improvement on plate tests would also occur if the tests were administered under Illuminant "A" (incandescent illumination), which is redder than the mandatory plate test Illuminant "C" (artificial daylight). For example, Hardy, Rand, and Rittler[6] administered the American Optical Company's printing of Ishihara plates to 12 Deutans and 10 Protans under both illuminants and the percentage of plates read correctly increased from 37 per cent under "C" to 69 per cent under "A" for the Deutans and from six per cent under "C" to 20 per cent under "A" for the Protans.

Another historical example occurred during World War II, when color defectives, eager to be accepted into the Navy, Air Force, and Officer Training Programs, sought a cure. Many "cures" were available at that time: electrical stimulation of the eye balls; injections of iodine; staggering doses of various vitamins; "education" (coaching to pass color vision tests); "education" in color naming and color matching; staring at flashing red and green lights; and wearing colored goggles. The problem reached such proportions that, in 1946, the Army-Navy National Research Council Vision Committee requested from the American Committee on Optics and Visual Physiology a statement of the efficacy of corrective training. The request was referred to several authorities for investigation and their report was adopted by the American Academy of Ophthalmology and Otolaryngology, the American Ophthalmological Society, the Section on Ophthalmology of the American Medical Association, and the Association of Schools and Colleges of Optometry. The testimony was conclusive

". . . . that no method has been found for the correction of color blindness, whether called "color weakness," "color confusion" or "color defectiveness." Men can be coached to pass tests, but their physiologic deficiency cannot be repaired. Any claims to the contrary, any "treatment" which convinces operators that they can see colors they could not see before will decrease safety in transportation, decrease security in national defense, and decrease efficiency in industry."[5]

The advocates of the X-Chrom lens are to be commended for their care in emphasizing that the lens cannot cure but only assists the color defective in making color judgments. Nonetheless, the danger still exists that men will be given duties that they cannot perform.

The color defectives' improved ability to pass the pseudo-isochromatic plates still leaves the question of whether they also can make color judgments of which they are otherwise incapable—identifying navigational lights, aviation signal colors, railroad signal lights, manning color-coded consoles, wiring electronic equipment, etc. This is a crucial question for research. The data presented here, particularly the inability of the men to perform well on the Farnsworth Lantern and the 100-Hue Test, suggest that the X-Chrom lens does not effect a general improvement in the ability to discriminate colors in all circumstances.

The results of the extensive color vision testing of just two X-Chrom lens users is being reported at this time to counter the many supportive reports about this device, and to inform those in charge of qualifying personnel for tasks requiring good color vision that, even though an applicant may pass a plate test with his X-Chrom lens, we do not yet know if he is safe for making critical color judgments. A more comprehensive evaluation is planned in which persons representing all categories of color vision defects will be evaluated, with particular emphasis on their ability to perform operational tasks.

Summary

The effectiveness of the X-Chrom lens in alleviating the defective color vision of two men (a severe protanomalous trichromat and a dichromatic deuteranope) was evaluated with an extensive battery of color vision tests. The first man failed all tests except one without and with the X-Chrom lens. The second failed all tests without the lens; with the lens, he passed three tests but performed significantly poorer on two other tests. It is emphasized that color vision tests are designed to be used only under standard illumination, and that passing such tests under non-standard conditions does not signify normal color vision. These results provide no evidence that the X-Chrom lens corrects color deficiency.

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